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A Dynamic Conceptual Model to Explore Technology-Based Perturbations to a Complex System: The Land Force

Neville J Curtis and Peter J Dortmans

DSTO Land Operations Division

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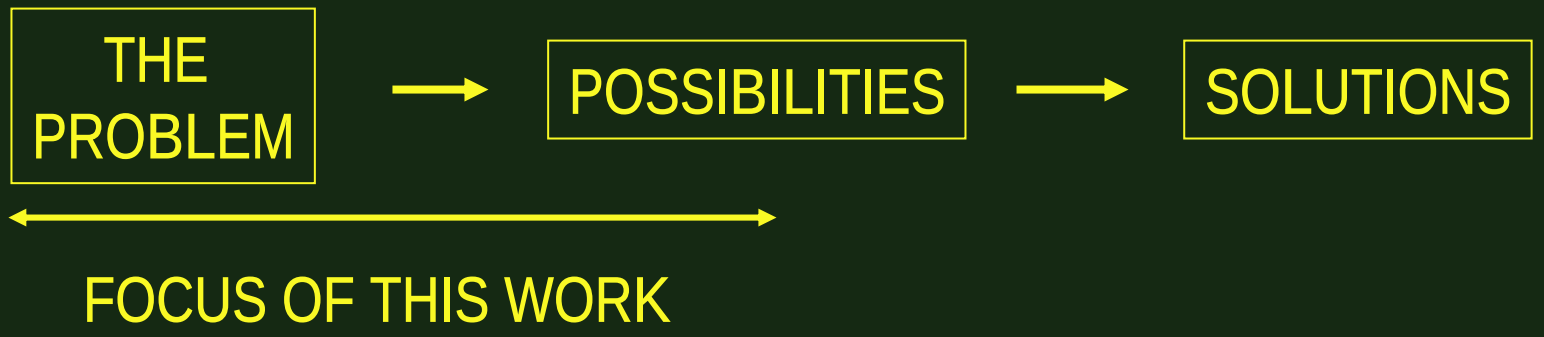
Outline - we will present:

- The problem of trying to enhance a complex system like the Land Force with technology
- A conceptual model of the Land Force and technological change
- A means of gaining semiquantitative insights
- Application examples:
  - Which items are more important for technology insertion?
  - What broad areas of research should we undertake?
  - For a specific technology, what strategy should we adopt?

The Problem

- The Land Force system is complex and comprises:
  - People and organisations
  - Equipment and formations
  - Specialist tasks
  - The environment
- How do we best apply technology to enhance this complex system?



The Conceptual Model: Elements

- Skills (the hows) that the Army needs to do the job
- A high level measure and how it is achieved for each skill
- An anisotropic influence diagram that links variables where position in the diagram has meaning
- A connectivity that links higher level goals, contributory measures and technology based factors
- Critical and high pay-off components
- Semiquantitative numerical values
- Interactions between skills that lead to synergisms and antagonisms

Army as a System Descriptors

- Engagement (E)
- Information collection (I)
- Sustainment (S)
- Communication (C)
- Protection (P)
- Movement (M)
- Decision Making (D)
- *(self explanatory titles)*

(Curtis/Dortmans, Land Warfare Conference (2001), p 364-381, based on Curtis, Land Warfare Conference (2000), p 314-327 and Hobbs/Goyne/Curtis, SMi Conference on Next Generation Technology (2000)

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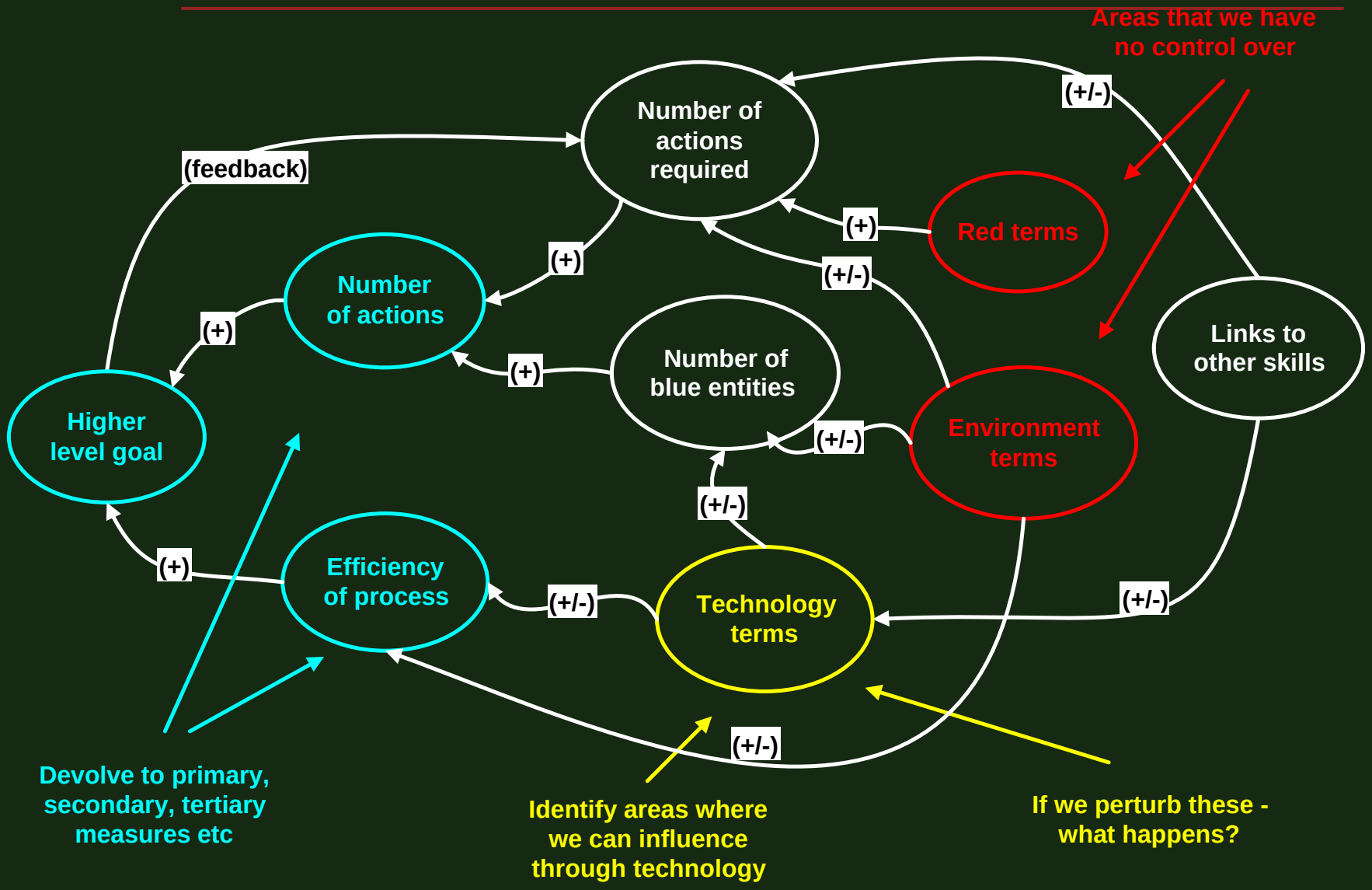
Generic influence diagram



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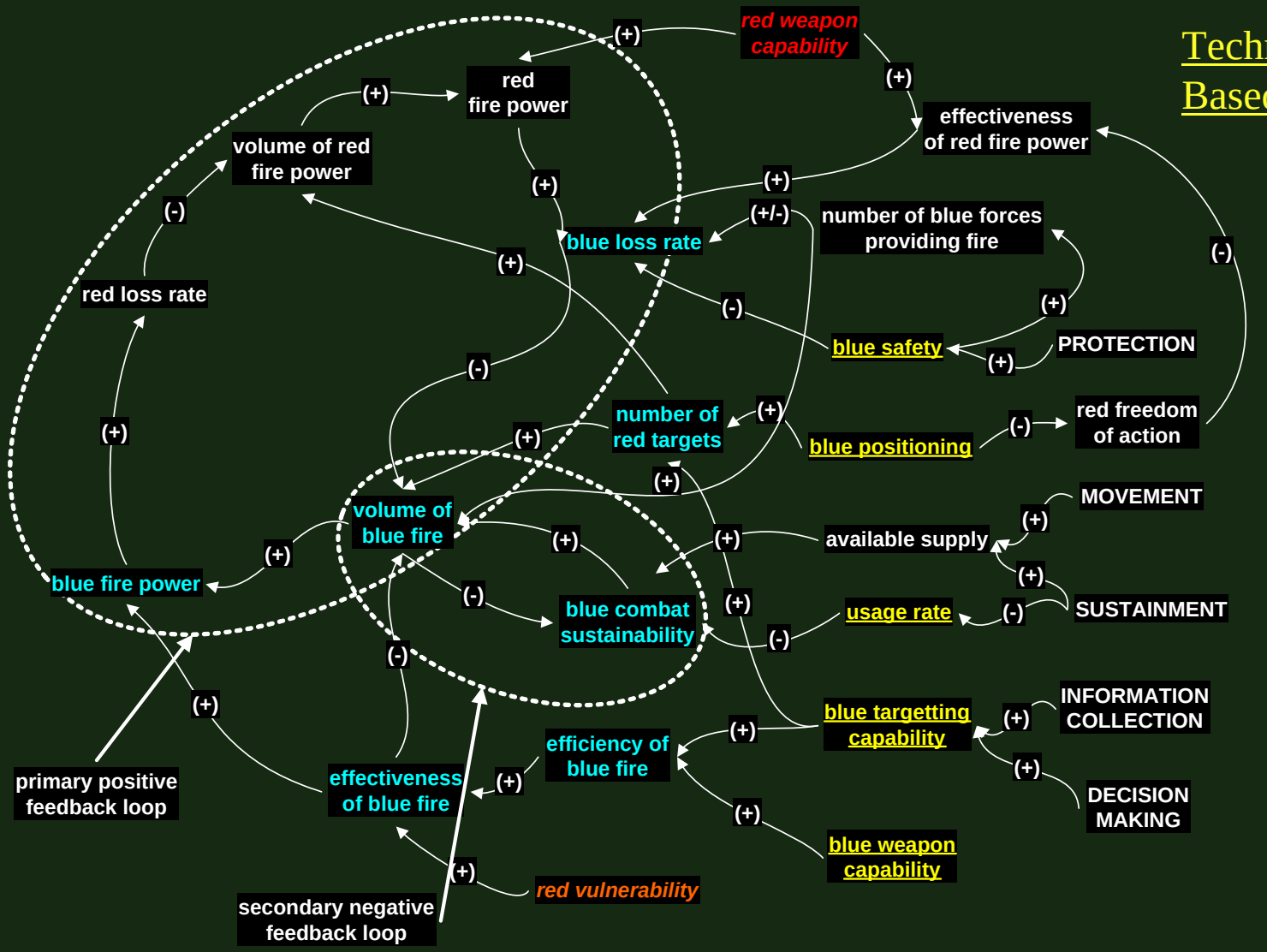
Example for "Engagement"



Technology Based Variables

Results for “Engagement” - Technology Based Variables (TBV)

- High pay-off - leads to many points in the diagram
  - “blue targetting capability”
- Critical - leads directly to a primary or secondary measure
  - *none for “engagement”*
- Less important
  - “blue safety”
  - “blue positioning”
  - “usage rate”
  - “blue weapon capability”

What is the current value of our capability?

If we have a 4 point scale for each skill, eg for “engagement”

- E_4: very high effectiveness
- E_3: high effectiveness but deficiencies in some cases
- E_2; moderate effectiveness with deficiencies in several areas
- E_1: limited effectiveness

then we have a scale to judge technological capability in the form:

$$E_eI_iS_sC_cP_pM_mD_d$$

Method - we assess the value of each TBV according to this scale, and apply weightings – high and critical pay-off worth twice the others

We can propose a current “capability description” of:

- $E_{1.6}I_{2.3}S_{2.3}C_{2.6}P_{1.5}M_{2.3}D_{1.3}$ —> $E_2I_2S_2C_3P_2M_2D_1$
- ie we have a measurable (but subjective) baseline

Perturbations to the current value – synergisms and antagonisms

- If we increase the capability of each of these Technology Based Variables, what is the effect on the “System”?
- NB changes may be good (synergism) or bad (antagonism)
- Level 1 - within the same skill
  - high pay-off and critical are factored more than the others
- Level 2 - between the skills
- Determined through the requirements and impacts
  - *NB these tend to mirror each other but this is done to ensure that everything is covered*

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Example - pay-off matrix for engagement (impacts shown)

	E	I	S	C	P	M	D
blue safety (Ea)	++(B) -(R)				+(B)		
blue positioning (Eb)	++(B) -(R)				-(R)		
usage rate (Ec)	+(B) -(R)		-(B)			-(B)	
blue targetting capability (Ed)	++(B) -(R)	-(R)	+/-(B) -(R)		-(R)	-(R)	+(B)
blue weapon capability (Ee)	+(B) -(R)	-(R)	+(B) -(R)				
number of blue force providing fire (E_f)	++(B) -(R)		-(B)	-(B)	+(B)	-(B)	

++(B) has a large positive effect on the blue force
-(R) has a smaller negative effect on the red force

Diversion

- The Army as a System model is based on perceptions of the effectiveness and feasibility of combinations of core skills.

  We might question the ability of two sides that have equivalent equipment to both attain E_4 and P_4

  - Unstoppable weapons and totally protected targets?

  We also know what has “worked” in the past

- An accompanying paper at this conference (Boswell, Curtis, Dortmans and Tri) will discuss a related piece of work that employs Field Anomaly Relaxation and historical analysis to identify reasonable combinations of skills, and the use of Agent Based Distillations to play these out

Applications

- *Example* 1: (requirements pull):
  - Where do we most need technology?
- *Example* 2: (technology push):
  - Which technology should we research to give best pay-off?
- *Example* 3: (comparative analysis)
  - Which option do we choose?

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Example 1 - if we globally enhanced all TBVs in each skill what would be the system effect?

	new blue state	new red state	sum of *raw score* blue differences from initial state	sum of *raw score* differences between blue and red
no change	$E_2I_2S_2C_3P_2M_2D_1$	$E_2I_2S_2C_3P_2M_2D_1$	-	-
E	$E_2I_2S_2C_3P_2M_2D_1$	$E_1I_2S_2C_3P_1M_2D_1$	1.0	2.2
I	$E_2I_3S_2C_3P_2M_2D_2$	$E_1I_2S_2C_3P_2M_2D_1$	1.9	2.5
S	$E_2I_2S_3C_3P_2M_3D_1$	$E_2I_2S_2C_3P_2M_2D_1$	2.0	2.0
C	$E_2I_2S_2C_3P_2M_2D_1$	$E_2I_2S_2C_3P_2M_2D_1$	1.0	0.9
P	$E_2I_2S_3C_3P_2M_3D_1$	$E_1I_2S_2C_3P_2M_2D_1$	2.0	2.3
M	$E_2I_2S_3C_3P_2M_3D_1$	$E_2I_2S_2C_3P_2M_2D_1$	1.8	1.8
D	$E_2I_2S_2C_2P_2M_2D_2$	$E_2I_2S_2C_3P_2M_2D_1$	1.5	1.5
all	$E_4I_3S_4C_3P_3M_4D_3$	$E_1I_2S_2C_3P_1M_2D_1$	11.2	13.0

Protection technologies followed by information collection and sustainment technologies seem to offer the best pay-off

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Example 2 - which of the future technologies identified in the NATO 2020 study are more promising?

	new blue state	new red state	sum of *raw score* blue differences from initial state	sum of *raw score* differences between blue and red
no change	$E_2I_2S_2C_3P_2M_2D_1$	$E_2I_2S_2C_3P_2M_2D_1$	-	-
precision attack	$E_2I_2S_3C_2P_2M_2D_2$	$E_1I_2S_2C_3P_1M_2D_1$	1.5	2.1
sensing, information fusion & digitisation	$E_2I_3S_3C_3P_2M_3D_3$	$E_1I_2S_2C_3P_1M_2D_1$	5.3	6.3
non-lethal weapons	$E_2I_2S_2C_3P_2M_2D_1$	$E_2I_2S_2C_3P_2M_2D_1$	not amenable to analysis	
robotics	$E_3I_3S_3C_3P_2M_3D_1$	$E_1I_2S_2C_3P_1M_2D_1$	3.8	4.7
simulation	$E_2I_2S_2C_3P_2M_2D_2$	$E_2I_2S_2C_3P_2M_2D_1$	*0.8*	*0.8*
modular systems	$E_2I_2S_3C_3P_2M_3D_1$	$E_2I_2S_2C_3P_2M_2D_1$	0.8	0.8
all	$E_3I_3S_4C_3P_3M_4D_3$	$E_1I_2S_2C_3P_1M_2D_1$	8.4	8.9

Sensing etc and robotics are best singles and overall it is a balanced program
Simulation comes out poorly as training issues are not in the original model

Example 3 - which is the best way to exploit hybrid engines?

- Two options:
  1. Reduce the weight and increase range
  2. Increase firepower and protection
- Results:
  - Option 1: new Blue $E_2 I_2 S_3 C_3 P_2 M_3 D_1$
    new Red $E_1 I_2 S_2 C_3 P_2 M_2 D_1$
    enhancement to blue = 2.8 ●
    differential blue-red = 2.9 ●
  - Option 2: new Blue $E_3 I_2 S_3 C_3 P_2 M_3 D_1$
    new Red $E_1 I_2 S_2 C_3 P_2 M_2 D_1$
    enhancement to blue = 3.6 ●
    differential blue-red = 4.5 ●

Summary

- This is a semiquantitative method to gain *insights* into possible directions of technology insertion
- Although we have used this for Land Force capability development it could be used in many areas
- Importantly the technique is “solution” free as it concentrates of the generic “what is needed” not “how we do it now”